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ABSTRACT

In this paper, animated pedagogical agents are looked at from an instructional design perspective. A "support-typology" was constructed based on different dimensions on which support can be described and different roles instructional agents can assume. This typology is used to analyze currently available pedagogical agents. This analysis indicates that current pedagogical agents are designed to provide support on content and problem solving aspects of the task and that they are capable of adapting their support to learning paths. The review of research on the relation between pedagogical agents and learning indicates that, although only limited research has been done, certain agent characteristics are relevant to take into account in further research on the effect of agents on learning. It can be concluded that pedagogical agents offer opportunities to be grasped in open learning environments. (Contains 38 references, 1 figure, and 1 table.) (Author)

Animated pedagogical agents: Where do we stand?

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Abstract
In this contribution animated pedagogical agents are looked at from an instructional design perspective. A 'support-typology' was constructed based on different dimensions on which support can be described and different roles instructional agents can assume. This typology is used to analyze current available pedagogical agents. This analysis indicates that current pedagogical agents are designed to provide support on content and problem solving aspects of the task and that they are capable of adapting their support to learning paths. The review of research on the relation between pedagogical agents and learning indicates that, although only limited research has been done, certain agent characteristics are relevant to take into account in further research on the effect of agents on learning. It can be concluded that pedagogical agents offer opportunities to be grasped in open learning environments.

Introduction

Open learning environments with a high level of learner control have been argued to foster the acquisition of complex problem solving skills (Jonassen, 1997). However, research indicates that students do not optimally use these support tools (e.g., Clarebout, et al., 2000; Land, 2000). It is wondered in this contribution whether pedagogical agents might be able to enhance the optimal use of support devices in open learning environments.
Pedagogical agents are animated characters designed to operate in educational settings for supporting learning. They can provide non-verbal feedback through means of facial expressions and gestures (Johnson, et al., 2000).
Adapting support to the need of individual learners is an important issue in designing learning environment, since providing either too many or too less support may be detrimental for learning (Clark, 1991).
In order to explore different ways in which pedagogical agents can adapt support to learning needs and enhance the use of support devices, currently available agents were analyzed, using a 'support' typology. After presenting this typology, the analysis of the pedagogical agents is discussed in the second part. A final part presents an overview of research with respect to pedagogical agents and learning. This part gives insight in the extent pedagogical agents have been proved to be beneficial to learning. The discussion and conclusion summarizes the results of the analysis and tries to provide an answer to the question whether these agents might enable to enhance the optimal use of support devices in open learning environments.

Support typology for pedagogical agents

Elen (1995) proposed a scheme with five dimensions to describe support initiatives: amount, formal object, topical object, delivery system and timing of support. This scheme was adapted and elaborated to construct the support typology for pedagogical agents. The support typology has 6 dimensions that look as follows (see Figure 1):

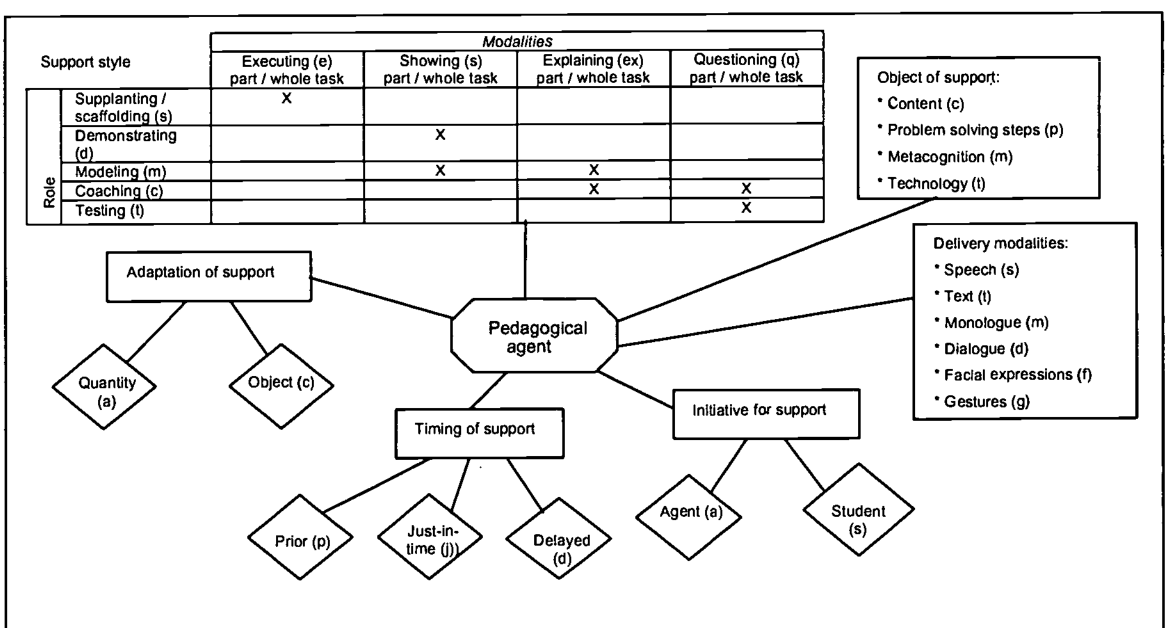
- *Object of support*: support can be directed to different aspects involved in solving complex problems (see also Hill & Hannafin, 2001): content of the task, problem solving steps, metacognitive strategies and handling the technology.
- *Learner control with respect to support:* open learning environments imply by definition a great deal of learning control (Hannafin, 1995). However, since students seem not always capable of making adequate choices with respect to their learning process (e.g., Large, 1996) and given that reviews on learner control do not reveal a consistent positive effect (see for example Niemic, et al., 1996) this aspect requires further investigation. Pedagogical agents can initiate support delivery, students may request support or decisions about support provision can be shared.
- *Adaptability of support:* learners differ with respect to the amount of support needed, depending on their prior knowledge (Ross, et al., 1980) and other learner characteristics such as aptitude and metacognitive skills (Clark, 1990). However, not only the amount of support might be adapted, also the object of support. Learners might need support on the level of the content of the task or on a more metacognitive level. Change in quantity and object of support can be determined by the agent and / or the learner.
- *Delivery modalities:* Pedagogical agents can entail different delivery modalities, which might affect their effect (Moreno, et al., 2000). Pedagogical agents can communicate verbally or non-verbally. Reeves and Nass (1996)

indicate that students view the interaction with a computer (c.q. pedagogical agent) as a social interaction in which three features are essential, namely: image, voice, and personalized language. Pedagogical agents have by definition an image. Hence, this distinction is not included in the typology. The other two features are. A distinction will be made between pedagogical agents using verbal (text or speech) and / or non-verbal language (head nods, gestures, facial expressions). Pedagogical agents can also communicate in a personal way, engaging in a dialogue, or in a more formal way, trough a monologue.

- *Timing of support:* support can be delivered at different moments during the learning process. van Merriënboer (1997) distinguishes between information relevant to recurrent aspects (rules, procedures, prerequisites) and to non-recurrent aspects (system, approaches, heuristics). Support for recurrent aspects should consist of just-in-time information and immediate feedback on the quality of the performance. Support for non-recurrent aspects should consist of both information presented up front and delayed. A pedagogical agent can deliver support either up front, just-in-time or delayed.
- *Support style:* this dimension refers to different roles and modalities instructional agents, in this case pedagogical agents, can assume. Literature suggests six typical roles for instructional agents:
  - supplanting: instructional agents take over the tasks and perform them for the learners. The learners observe the instructional agents (e.g. Salomon, 1994);
  - scaffolding: instructional agents perform those parts of the task that the learners are not yet able to perform independently (e.g., Jonassen, 1996);
  - demonstrating: instructional agents show how a task if performed after which they observe how the learner performs the task (e.g. Merrill, 1994);
  - modeling: instructional agents show how a task is performed while revealing and explaining their reasoning process. They solve a task while they articulate how problems are solved, what strategies are used and what mental models are necessary to understand the task (e.g., Jonassen, 1996);
  - coaching: instructional agents provide hints and feedback, activate learners when they perform the task. Instructional agents observe the learners and provide guidance when they experience difficulties (e.g., Barab & Duffy, 2000), and
  - testing: instructional agents tests the learners' knowledge about certain aspects of the task in order to guide the learning process (e.g., Martens & Dochy, 1997).

These roles can be characterized by (a combination of) four analytical modalities: executing, showing, explaining and questioning. For instance, if the role of the instructional agents is coaching, support can consist of a combination of explaining and questioning. Executing means that an instructional agent performs the task for the learner. Learners observe the instructional agent but do not perform the task themselves. Showing involves the demonstration of the task by an instructional agent after which the learners perform the task themselves. Explaining involves an instructional agent who clarifies the task while the learner performs it. Questioning means asking questions about the task to the learner.

These different modalities may involve the task or part of it and instructional agents may shift between different roles for different parts of a task.



Support style		Modalities: Executing (e) part / whole task	Showing (s) part / whole task	Explaining (ex) part / whole task	Questioning (q) part / whole task
Role	Supplanting / scaffolding (s)	X			
	Demonstrating (d)		X		
	Modeling (m)		X	X	
	Coaching (c)			X	X
	Testing (t)				X

Figure 1: Support-typology for pedagogical agents

Analysis of different pedagogical agents

Methodology

To identify current available pedagogical agents, ERIC, PSYCINFO and the Internet (using the Google-search engine) were searched. Reference lists in texts generated through these searches were also used to find more information (snowball-method). This resulted in the agents presented in Table 1. Key words used to find information on these agents were 'pedagogical agent', 'animated agent', 'agent and virtual reality', 'agent and multimedia', 'personal digital agent'. Only agents used in educational setting were selected. Previous reviews of pedagogical agents have been presented by Johnson et al. (2000, 2001). They came to a similar list, although their review was not restricted to agents operating in educational settings and was focussed on the technological aspects of these agents. In the following a short description is provided of the different agents, the actual analysis is presented in Table 1.

Description of the different pedagogical agents

Adele (Shaw et al., 1999; Ganeshan, et al. 2000): Adele supports distance learning in the domain of medicine and dentistry. She exists in three different interaction modes. In the advisor mode, she observes the students when performing an action. She interrupts and makes suggestions when there is an inconsistency with the standard practice. In the practice mode, Adele provides advice only on request of the student. A final mode is the examination mode where she provides only an evaluation after the students have finished. Recent developments made Adele more focussed on guiding students in their problem solving process.

Steve (Johnson et al., 2000): Steve is an acronym for Soar Training Expert for Virtual Environments. He demonstrates 'skills' involved in a specific task. The student can walk around in the environment while Steve demonstrates part of the tasks and explains what he is actually doing (modeling). The student can interrupt the agent and ask to finish the task.

Herman the Bug (Lester, et al., 1999a): Herman is an alien with human-like movements and facial expressions. He inhabits a learning environment called 'design-a-plant' for the domain of botanical anatomy and physiology. Herman gives advice, encourages students and provides feedback.

Cosmo (Lester, et al., 1999b): Cosmo inhabits the Internet Advisor learning environment for the domain of Internet packet routing. Cosmo provides advice to learners and explains content and problem solving related issues.

WhizLow (Johnson et al., 2000; Grégoire, et al., 1999): WhizLow inhabits CPU City, a three dimensional learning environment representing a motherboard. Students are given programming tasks. WhizLow carries out instructions given by the students and traces misconceptions of students that are corrected by providing advice.

PPPersona (André et al., 1999): The PPPersona agent, is an animated agent for presenting on-line instruction. The agent guides learners through web-based materials, he demonstrates the information.

Jacob (Evers & Nijholt, 2000): Jacob instructs and assists users performing a task in a virtual environment (e.g. tower of Hanoi). Jacob gives feedback on the user performance and can demonstrate the task if necessary.

Gandalf (Cassell, & Thorisson, 1999): Gandalf is an expert in the solar system and the user can ask him questions about specific planets. Gandalf will virtually travel to these planets when a question is asked and give an explanation when the student asks for it.

Autotutor (Graesser, et al., 1999): Autotutor is designed to assist college students in learning the fundamentals of hardware, operating systems and the Internet. Autotutor presents questions to the students to test their knowledge.

In Table 1 the analysis of these different agents is presented following the support typology.

Table 1: Analysis of different pedagogical agents

	Modality	Role	Object	Adaptation	Delivery modality	Control	Timing
Adele	ex, q	c	c, p, t	a, o	s, t, d, m, f, g	a, l	j, d
Steve	s, ex	d, m, c	c, p, t	a, o	s, d, m, f, g	a	p, j
Herman the Bug	ex	c	c, p	a, o	s, d, m, f, g	a	j
COSMO	ex	c	c, p	a, o	s, d, m, f, g	a, l	j
WhizLow	e, ex	s, c	c	a	s, m, d, g	a, l	j
PPPersona)	s	d	c	-	s, m, f, g	a	-
Jacob	s, ex	d, c	p	a	t, d, f, g	a, l	j
Gandalf	s, ex	d, c	c	a	s, m, d, f, g	l	j
Autotutor	t, ex	q	c	-	t, m, d, f, g	a	-

The analysis reveals different aspects:

1. Most agents are designed to act as a coach. The agent provides hints and feedback while the learner solves a problem. Sometimes demonstration of parts of the task is also included (e.g. Steve).
2. Explaining is most frequently used as a modality, complemented by questioning.
3. For all agents, except for Jacob, the main object of support is the content. Some of the agents also provide support on the level of problem solving. Jacob for example provides only support on the level of problem solving. Steve and Adele also support the use of the environment.
4. All agents are technologically able to communicate both verbally and non-verbally. Most agents use speech. Some use both speech and text. Dialogue as communication is mostly used.
5. Just-in-time support is used frequently.

Research results

The analysis of pedagogical agents reveals that agents are already used in learning environments to support learning. In this part an overview is presented of empirical research about the relationship between learning and pedagogical agents. Lester, et al. (1997) performed a study to measure agents' affective effects on learning. Five 'clones' of Herman the bug were studied: 1) a fully expressive one, giving principle-based animated advice as well as task-specific audio-advice, 2) one who gave only principle-based animated advice, 3) a clone who gave principle based but only verbal advice, 4) one giving task-specific verbal advice, and 5) a mute one. All other features remained identical. Results show that all students performed significantly better on the posttest. The smallest and highest increase in performance was for the students in the 'mute' and the fully expressive condition respectively. Results on an assessment questionnaire show significantly higher scores for the personal assessment of the agent (utility of the advice and feedback of the agent). Given also the increase on the post-test for the 'mute' condition, Lester et al. conclude that there exists a persona-effect. The merely presence of an agent increases the scores. This persona-effect however was not found by André et al. (1999), who created two versions of their learning environment, one with PPPersona and one without.
Moreno, et al. (2000) compared two groups of students working in a discovery learning environment. One group had a pedagogical agent (Herman the Bug), while the other received text-based information. No significant difference was found for retention. For a transfer test a significant difference was found in favor for the group with the pedagogical agent. This group showed also a greater interest and motivation. In a follow up study Moreno et al. (2000) experimented with pedagogical agents varying on the three features of social interaction mentioned by Reeves and Nass (1996): image, voice, and personalized language. The studies indicated that the condition in which an agent with voice was used instead of text resulted in better results for retention and transfer. The sheer presence of an image of the pedagogical agent had no effect. The kind of communication (dialogue versus monologue) influenced the results for the retention test in favor of the dialogue mode (see also Moreno & Mayer, 2000). In other experiments, Moreno, et al. (2001) experimented with the type of image. The image of Herman was compared to a video-based image of a real person. No effects were found for this variable on retention and transfer.
In addition to these quasi-experimental studies two, more informal, evaluation studies can be mentioned. The first one relates to an evaluation of Steve (Johnson, et al., 1998). It suggests that interacting with agents in a virtual environment be perceived as more natural than using conventional text-based tutoring interfaces. The second study deals with Adele (Shaw et al., 1999). Students indicated in a survey to appreciate the support provided by Adele. Moreover, students preferred to hear a rationale only when they asked for it (practice mode). Nevertheless experience suggests that students do not ask for advice when given the choice.

Discussion and conclusion

An analysis was made of current available pedagogical agents. To do this analysis, first a support-typology was constructed. This typology provides a common framework to describe and discuss pedagogical agents. The analysis reveals that most pedagogical agents act as coaches and provide support on the level of the content and problem solving. Most of the pedagogical agents are capable of adapting quantity and object of support to learners' action. It can be concluded that pedagogical agents are capable of adapting support to the needs of the learner by reacting to the learning path followed.
However, none of these pedagogical agents provide metacognitive support, while such support has been recognized as important (Hannafin, 1995, Shuell, 1992). This might be explained by the origin of pedagogical agents. Pedagogical agents evolved from research on intelligent tutoring systems (Shaw et al., 1999), which are systems focussing strongly on the acquisition of domain specific knowledge (Shute & Psotka, 1996). These tutoring systems were developed, starting from teaching goals and aiming at how to replace a human tutor by an intelligent tutoring system (Derry & Lajoie, 1993) and mostly work with well-structured problems for which one solution exists. The analysis of pedagogical agents demonstrates that, even now, most agents are used in situations that do not require students to solve complex problems but rather procedural tasks for which an optimal solution exists (e.g. Jacob, PPPersona). So, the answer to the question 'where do we stand?' would be that pedagogical agents provide a more sophisticated intelligent tutoring system. However, to develop pedagogical agents able to operate in open learning environments in which students have

control over their learning and work on a complex task, a different perspective might be indicated. Rather than starting from a teacher-oriented perspective (how to model a good tutor), a student-oriented perspective might be advocated. Rather than starting from focussing on the acquisition of domain specific knowledge, and representing a complete domain-model, metacognitive processes could be focussed upon to enable students to monitor their own learning process.

Pedagogical agents operating in open learning environments and delivering support on a metacognitive level might encourage learners to make more ample and deliberate use of support in open learning environments. Hill and Hannafin (2001) for example argue that students lack the necessary skills to monitor their learning and to make appropriate choices with respect to support devices in the learning environment.

Research on intelligent tutoring systems focussed on whether these systems were a 'good' replacement of a human tutor (e.g., Schofield, et al., 1994), research on pedagogical agent should focus on the influence of these agents on (aspects of) the learning process, considering research findings with respect to agent characteristics (Lester et al., 1997; Moreno et al., 2000) and learner variables (Shaw et al., 1999).

Taking a more learner-oriented perspective into account in the development of pedagogical agents and focussing on supporting students on the level of their metacognitive skills could result in pedagogical agents able to enhance the (optimal) use of available support devices in open learning environments.

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